ORIGINAL RESEARCH PEER REVIEWED

Investigation of the use of meloxicam for reducing pain associated with castration and tail docking and improving performance in piglets

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Summary

Objectives: To determine the effect of meloxicam, administered to suckling piglets prior to castration and tail docking, on growth and mortality, and to determine evidence of pain reduction.

Materials and methods: Piglets (n = 2888) were alternately assigned either to meloxicam (extra-label use) or a placebo injected intramuscularly 30 minutes prior to processing, which included tail docking for females, and tail docking and castration for males. All piglets were weighed on the day of processing (5 to 7 days of age) and at weaning (19 to 21 days of age). Vocalization scoring during castration, behavioral observations, and analysis of plasma cortisol concentrations were performed on a subset of animals.

Results: Growth was not associated with treatment, but was positively correlated with weight at processing and negatively correlated with litter size. Mortality did not differ between treatment groups, but there was an interaction between treatment and parity, with piglets nursing older sows (parity > 5) and treated with placebo being 4.4 times more likely to die than piglets nursing older sows and treated with meloxicam (95% CI, 1.31-14.3) (P = .01). Behavior scores for isolation (isolating themselves from the other pigs) and plasma cortisol concentrations were higher for placebo-treated piglets than for meloxicam-treated piglets (P < .05).

Implications: Routine treatment of piglets with meloxicam prior to castration and tail docking (extra-label use) does not improve growth, but may reduce mortality in litters nursing older sows. Observations of behavior and analysis of cortisol concentrations indicate meloxicam treatment does reduce pain.

Keywords: swine, castration, meloxicam, pain, growth

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Resumen - Investigación de la utilización del meloxicam para reducir el dolor asociado con la castración y el corte de cola y para mejorar el desempeño de los lechones

Objetivos: Determinar el efecto del meloxicam, administrado a lechones lactantes antes de la castración y del corte de cola, en el crecimiento y mortalidad, y determinar la evidencia en la reducción de dolor.

Materiales y métodos: Se asignaron lechones (n = 2888) alternativamente a meloxicam (uso de fuera de etiqueta) o a un placebo inyectado intramuscularmente 30 minutos antes del procesamiento de las camadas, que incluía corte de cola para las hembras y corte de cola y castración para los machos. Se pesaron todos los lechones en el día de proceso (5 a 7 días de edad) y en el destete (19 a 21 días de edad). Durante la castración se efectuaron valoraciones de vocalización, observaciones de la conducta, y análisis de la concentración de cortisol de plasma, en un subconjunto de animales.

Resultados: El crecimiento no estaba asociado con el tratamiento, pero se correlacionó positivamente con el peso al momento del proceso y se correlacionó negativamente con el tamaño de la camada. La mortalidad no difirió entre los grupos de tratamiento, pero hubo una interacción entre tratamiento y paridad; esto es, los lechones lactando de hembras adultas (paridad > 5) y los tratados con placebo tuvieron 4.4 veces más posibilidad de morir que los lechones lactando de hembras adultas y tratados con meloxicam (95% CI, 1.31-14.3) (P = .01). Los valoraciones de conducta por aislamiento (aislándose ellos mismos de otros cerdos) y las concentraciones de cortisol de plasma fueron mayores en los lechones tratados con placebo que en los lechones tratados con meloxicam (P < .05).

Implicaciones: El tratamiento rutinario de lechones con meloxicam antes de la castración y del corte de cola (uso fuera de etiqueta) no mejora el crecimiento, pero puede reducir la mortalidad en camadas lactando de hembras adultas. Las observaciones de conducta y el análisis de las concentraciones de cortisol indican que el tratamiento de meloxicam reduce el dolor.

Résumé - Étude sur l'utilisation du meloxicam dans le but de réduire la douleur associée à la castration et la taille de la queue et améliorer les performances chez les porcelets

Objectifs: Déterminer les effets du meloxicam administré à des porcelets à la mamelle avant la castration et la taille de la queue sur la croissance et la mortalité, et déterminer l'évidence de réduction de la douleur.

Matériels et méthodes: Des porcelets (n = 2888) ont été assignés en alternance au groupe recevant une injection intramusculaire de meloxicam (utilisation hors-homologation) ou un placébo 30 minutes avant les procédures qui incluaient la taille de la queue pour les femelles, et la taille de la queue et la castration pour les mâles. Tous les porcelets étaient pesés le jour des procédures

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(5 à 7 jours d'âge) et au sevrage (19 à 21 jours d'âge). La vocalisation durant la castration, les observations du comportement, et l'analyse des concentrations plasmatiques de cortisol ont été effectuées sur un sous-groupe d'animaux.

Résultats: La croissance n'était pas associée avec le traitement mais était corrélée positivement avec le poids au moment du processus et corrélée négativement avec la taille de la portée. La mortalité ne différait pas entre les groupes, mais il y avait une interaction entre le traitement et la parité, les porcelets allaités par des truies plus âgées (> 5 parités) et traités avec le placébo étant 4,4 fois plus susceptibles de mourir que les porcelets allaités par des truies plus âgées et traités avec du meloxicam (IC 95%, 1,31-14,3) (P = ,01). Les pointages de comportement pour l'isolement (animaux s'isolant des autres porcs) et les concentrations plasmatiques de cortisol étaient plus élevés pour les porcelets traités avec un placébo comparativement aux porcelets traités avec du meloxicam (P < ,05).

Implications: Le traitement de routine avec du meloxicam préalablement à la castration et à la taille de la queue (utilisation hors-homologation) n'améliore pas la croissance, mais pourrait réduire la mortalité chez les porcelets allaités par des truies plus âgées. L'observation des comportements et l'analyse des concentrations de cortisol indiquent que le traitement avec du meloxicam réduit la douleur.

In North America, piglets raised under modern production conditions undergo a number of surgical procedures, including tail docking and castration of males. These procedures are generally performed without pain control such as anesthetic or analgesia. Research studies have shown that castration of piglets is painful,[1-3] as is tail docking.[4,5] From a welfare standpoint there is a need to examine how pain control might be practically and economically applied to improve welfare of suckling piglets undergoing these procedures.

Non-steroidal anti-inflammatory drugs (NSAIDs) are becoming licensed for use in food-producing animals, providing an opportunity to address the need for pain control during and after piglet processing. The relatively long-acting NSAID meloxicam has been studied extensively for its analgesic properties in various species[6] and may prove useful in dealing with pain associated with piglet castration and tail docking. Most studies that have investigated the use of meloxicam as an aid in reducing post-operative pain and stress in piglets have been relatively small controlled trials emphasizing behavior and physiology to determine the level of pain control. Keita et al[7] showed that pre-operative administration of meloxicam resulted in lower plasma cortisol concentrations and adrenocorticotropic hormone after surgical castration than in controls and mitigated behavioral alterations indicative of pain between 2 and 24 hours after the procedure. Similarly, Hansson et al[8] demonstrated that piglets receiving meloxicam after castration displayed less pain-related behavior on both castration day and the following day than did those not given meloxicam. However, these studies have been relatively small and therefore not able to adequately measure analgesic effects on growth performance and mortality under commercial production conditions. In order for producers and veterinarians to judge the cost-benefits of instituting an analgesic regimen as part of piglet processing, a large field trial is required to determine if analgesia affects performance.

The objectives of this study were primarily to determine the effect of meloxicam administered as a routine measure to piglets prior to castration and tail docking on subsequent growth and mortality in the suckling period and, secondarily, to determine whether piglets treated with meloxicam prior to processing experienced less pain than controls.

Materials and methods

This study was approved by the University of Guelph Animal Care Committee in accordance with the Canadian Council of Animal Care Guidelines.

Herd and facilities

This study was carried out on a 600-sow commercial swine operation between May and November 2011. The sows were Landrace × Yorkshire crossbreds and the sires of the piglets were Duroc × Pietrain. All sows and litters were housed in fully slatted, mechanically ventilated farrowing rooms (four rooms containing 24 farrowing crates and one containing 12 crates). Heat pads were provided in the creep area of each crate. Piglets were fed by suckling their mother's milk. No additional diet was offered. Piglets had unlimited access to water nipples. No piglets were subjected to teeth clipping. The rooms were filled in an all-in, all-out manner and were cleaned and disinfected between groups.

Study design

This study involved 2888 piglets (1499 males and 1389 females) from 407 litters. Piglets received an injection of 200 mg of iron dextran and were ear notched within 48 hours of birth. Cross-fostering did occur in this herd prior to ear notching, but researchers were unable to document which pigs were moved from one litter to another. Once pigs were ear notched and litters identified for the study, no cross-fostering was allowed. At 5 to 7 days of age, piglets were weighed and alternately assigned to a treatment as they were picked up, with the first male pig given treatment A and the second male pig given treatment B; the females were assigned to a treatment in the same manner. Each piglet was identified by a number marked on the top of its head. Researchers were blind to treatment until the trial was complete. Treatment A was meloxicam (Metacam; Boehringer Ingelheim [Canada] Ltd, Burlington, Ontario, Canada; extra-label use) given at 0.4 mg per kg body weight, and treatment B was the same volume of a placebo (the vehicle for meloxicam, prepared by Boehringer Ingelheim [Canada] Ltd).

Piglets were returned to the farrowing crate for 30 minutes before processing. They were then picked up a second time, tail docked using side-cutters, and then castrated (if male) before being set down. Castration was carried out following methods of Van Beirendonck et al[9] by making an initial horizontal incision in the scrotum with a scalpel after which the testicles were removed by tearing the spermatic cords. Cryptorchid pigs and pigs with inguinal hernias were identified prior to treatment and not included in the study. Mortality data were collected daily. In addition, all piglets were individually weighed at processing and just prior to weaning (19 to 21 days of age) using a DYMO shipping scale (Pelouze, Albany, California). The scale had a maximum capacity of 68 kg and a resolution of 0.1 kg. Sows were categorized by parity and litter size at the time of the study.

Measurements

Weight at processing and weaning, as well as mortality data, were collected from all pigs. Additional measurements were undertaken in a smaller number of piglets to assess pain control. Vocalization was assessed during castration on a subset of 126 male piglets using a decibel meter (Decibel Meter Pro; Performance Audio for iOs devices, Apple Inc, Cupertino, California) to determine the amplitude of sound produced. The decibel meter was held as close to the snout as possible, without touching it, throughout the entire procedure. The call with the highest intensity level during the castration was recorded. Decibel (dB) is a unit for expressing the relative intensity or relative difference in

power between acoustic signals on a scale from 0 for the average least perceptible sound to approximately 130 for the average level causing pain. Decibels are the logarithm to base 10 (common logarithm) of the power ratio (I = 10 log (p1/p0). Because decibels are expressed as a logarithm scale, decibels were transformed to power gain units in Stata to meet the model assumptions of normality and homoscedasticity; for example 102 db = $10^{10.2}$ = 15,848,931,925 power gain units. For the interpretation of results, power gain unit values were re-transformed to decibels using an on-line calculator (available at **http://www.daycounter.com/Calculators/Decibels-Calculator.phtml**).

Behavior of piglets was scored for the period immediately following processing and for 30 minutes afterwards. On a day when several litters were to be castrated, one litter was chosen for observational studies. There was insufficient manpower to intensively monitor behavior in multiple litters at one time. Typically, a litter with at least four males and four females was chosen so that each treatment category was represented twice. Following tail docking and castration, piglet behavior was observed through continuous observation of instantaneous behaviors in15 litters (101 piglets). A total of 52 piglets (27 males and 25 females) were included in the meloxicam group and a total of 49 piglets (23 males and 26 females) were included in the placebo group. A detailed observation form with nine separate behaviors was used (Table 1), with the observer standing outside the farrowing crate and to the rear of the sow. Piglets were considered positive for a specific behavior if that behavior was observed during the period of observation.

Cortisol was measured in 236 blood samples representing piglets in 49 litters. Blood was collected in EDTA tubes at 30 minutes, 60 minutes, 90 minutes, and 4 hours after piglet processing. An individual pig was sampled once. A total of 119 pigs (56 females and 63 males) were included in the meloxicam group and 117 piglets (57 females and 60 males) in the placebo group. Blood was collected from 48 piglets in 16 litters at 30 minutes, from 44 piglets in 13 litters at 60 minutes, from 83 piglets in 11 litters at 90 minutes, and from 61 pigs in 9 litters at 4 hours after processing. In addition, 12 samples were collected from pigs prior to processing in order to establish a baseline. The blood samples were centrifuged at 3900*g* and 5°C for 20 minutes, 1 to 3 hours after collection. The plasma was stored in 2-mL micro tubes, PP (Sarstedt Inc, Montreal, Quebec) at -20°C until samples were analyzed for cortisol with a solid-phase, competitive chemiluminescent enzyme immunoassay (Immulite/Immulite Cortisol 1000; Siemens Healthcare Diagnostic Products Ltd, Oakville, Ontario, Canada). The test had an analytical sensitivity of 5.5 nmol per L with a calibration range of 28 to 1380 nmol per L.

Table 1: Piglet behaviors in a study to assess the effects of meloxicam on signs of post-operative pain*

Behavior	Description
Lying down	Body weight supported by belly or side
Standing	Body weight supported by four legs
Walking	Moving on four legs
Head low	Standing idle with the head held low, below the shoulder
Isolated	Lying or standing away from the main group of piglets
Tremble	Piglet's body is trembling
Tail-jam	Tail held tightly against body
Tail-wiggle	Tail wagging back and forth rather than hanging down, relaxed
Scooch	Piglet dragging its rump along the floor

* Behavioral observations were scored for 30 minutes after tail docking and castration for 52 piglets pretreated with meloxicam (Metacam; Boehringer Ingelheim [Canada] Ltd, Burlington, Ontario, Canada; 0.4 mg/kg intramuscularly; extra-label use) and 49 piglets receiving a placebo (vehicle for Metacam, prepared by Boehringer Ingelheim [Canada] Ltd). Piglets were considered positive when a specific behavior was observed.

Statistical analysis

Descriptive and quantitative statistical analyses were performed in Statistix (Statistix10, Version 10.1; College Station, Texas). Each continuous variable was plotted and tested for normality using the Shapiro-Wilk test. The correlation among continuous variables was tested using pair-wise correlations. The simple association between average daily gain, cortisol concentrations, and vocalization (decibels) and treatment and gender were evaluated with a two sample T-test when continuous variables were normally distributed and with the Wilcoxon rank sum test when variables were not normally distributed. The simple association of birth weight, weight at castration, weight at weaning, average daily gain, and litter size with parity categories was analyzed with a one-way analysis of variance when the variables were normally distributed and with a Kruskal-Wallis test when the variables were not normally distributed. Bonferroni correction was used to determine the significance among categories. A chi-square test was used to determine the simple association between treatments with behaviour variables, mortality, gender, and parity categories. Fisher's exact test was used in cases where the expected value in the 2 × 2 table was < 5 in at least one of the cells. A P value of < .05 was considered significant, and P values < .10 but > .05 were considered a trend.

Mixed linear regression models were used to determine the association of piglets' average daily gain (ADG) with treatment, parity, litter size, weight at castration, and gender. Individual interactions between treatment and parity, gender, litter size, and weight were evaluated for significance. In this model, treatment, parity, gender, litter size, and weight at castration were considered fixed effects, and the identity (ID) of the individual litter that each pig was born into was modeled as a random intercept. Models with and without the interaction terms of significant variables were compared using the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) values. These are two measures that provide information on the overall assessment of the model and can be used to compare models. Residuals were visualized after fitting the model to determine normality of residuals and the presence of unusual observations that would require further analysis.

The association of pig mortality from castration to weaning with treatment, gender, parity, litter size, and weight at castration were analyzed using a multilevel mixed effects logistic regression model. In this model, treatment, parity, gender, litter size, and

weight at processing were evaluated as fixed effects, and ID of the individual litter that each pig was born into was modeled as a random intercept. The interactions of treatment with parity, gender, litter size, or weight at processing were evaluated for significance.

Regression models were used to determine whether plasma cortisol concentrations and intensity of vocalization differed between meloxicam and placebo groups. A log transformation was performed for cortisol concentrations for the residuals to meet the model assumptions of normality and homoscedasticity. Decibels were transformed to power units. A logistic regression model was used to determine whether specific behavior categories after tail docking and castration differed between treatment groups.

Results

Pig performance

Weight at weaning and weight at processing were positively correlated with ADG ($P < .001$), and litter size at the time of piglet processing was negatively correlated with ADG ($P < .001$). Weight at weaning and ADG were normally distributed. Weight and litter size at the time of processing and parity were not normally distributed. Parities of the sows were categorized as parity 1-2 (Young), parity 3-5 (Mid-age), and parity > 5 (Old). Treatment was not significantly associated with ADG, weight at processing, weight at weaning, litter size, or parity ($P > .05$). A total of 105 piglets died between the time of processing and weaning. Mortality was not significantly different between pigs receiving meloxicam and piglets given a placebo ($P > .05$). A total of 48 of 1509 piglets (3.18%) died in the placebo group and 57 of 1484 (3.84%) died in the meloxicam group.

The placebo group included 787 males and 722 females, and the meloxicam group included 777 males and 707 females. Means and standard deviations of ADG by treatment groups and gender are summarized in Table 2. Average daily gain and mortality did not differ among treatment groups or between genders.

Litter size at the time of piglet processing ranged from four to 15 piglets. Parity and litter size at processing were categorized for further analysis. Parity was categorized as follows: Young, 915 piglets; Mid-aged, 730 piglets; and Old, 1348 piglets. Average daily gain differed among parity categories ($P < .001$). The average daily gain of piglets from Young sows was lower (0.161 kg) than that of piglets from Mid-age or Old sows (0.179 and 0.175 kg, respectively). Mortality differed by parity ($P < .001$). A total of 20 pigs died in the Young group (2.18%), 16 in the Mid-age group (2.19%), and 69 in the Old group (5.11%).

Litter size at processing was based on 50% percentiles: small litters with ≤ 10 pigs (1436 pigs) and large litters with ≥ 11 pigs (1557 pigs). Average daily gain differed between litter-size categories ($P < .001$). Pigs from large litters at the time of processing gained less weight (0.166 kg per day, standard deviation [SD] 0.05) than pigs from small litters (0.177 kg per day, SD 0.05). Mortality was not significantly different between litter-size categories: a total of 49 pigs (3.41%) died in small litters compared to 56 (3.59%) in large litters ($P > .05$).

The multivariable mixed linear models were built using ADG as a dependent variable. Treatment and gender and all possible interactions with treatment were not significant. Weight at the time of processing was significant in all models, and ADG varied significantly by litter ($P < .01$). In general, pigs that were heavier at processing gained more weight during the suckling period.

The mixed multi-level logistic models for mortality included treatment, weight at processing, and the interaction of treatment × gender, treatment × weight at processing, and treatment × parity. Mortality did not differ significantly between treatment groups; however, weight at processing differed significantly ($P < .001$) and mortality differed significantly ($P < .001$) between litter sizes. Pigs with lower weights at processing were more likely to die than heavier pigs. The interactions of treatment × gender or treatment × weight were not significant; however, pigs nursing Old sows in the placebo group were 4.4 times more likely to die (95% CI, 1.31-14.3) than pigs nursing Old sows in the meloxicam-treated group ($P = .01$).

Measurements of pain

Male pig vocalization. A total of 66 and 60 male pigs were included in the meloxicam and placebo groups, respectively. Intensity of vocalization ranged between 102 and 107 dB. The mean dB intensity for both the placebo group and the meloxicam group was 105 dB (SD 98.7; $P = .97$). The intensity of vocalization ("power gain") was not correlated with weight and age at castration ($P = .40$ and $P = .10$, respectively). The mean weight and age at castration of the 126 male pigs included in the vocalization test were 2.77 kg (SD 0.82 kg) and 5.61 days of age (SD 0.88 days), respectively. In the regression model, no significant differences in maximum amplitude of vocalization were observed between pigs receiving placebo and those treated with meloxicam ($P > .05$). Maximum amplitude of vocalization did not differ with respect to piglet weight or age at castration ($P > .05$), and none of the interactions were significant.

Pig behavior after tail docking and castration. A total of 101 pigs were evaluated for behaviour after tail docking and castration. The placebo group included 49 piglets (26 males and 23 females) and the meloxicam group included 52 piglets (27 males and 25 females). Lying down, standing, and walking were behaviors commonly observed in males after castration and tail docking and in females after tail docking. Head held low, "scooch" movement, and trembling (Table 1) were not significantly different between treatments. Isolation was the only behavior significantly different between meloxicam and placebo groups ($P < .05$).

Table 2: Mean ± standard deviation of average daily gain (ADG) and mortality by treatment group and gender from the day of tail docking (and castration of males) at 5 to 7 days of age to weaning at 19 to 21 days of age*

Treatment	n	ADG (g/day)	Mortality (%)
Males			
Meloxicam	743	171.9 ± 53.8	4.38
Placebo	756	173.6 ± 52.3	3.94
Females			
Meloxicam	684	169.3 ± 54.2	3.25
Placebo	705	172.3 ± 51.9	2.35
P†	NA	.48	.16

* Pigs were treated with meloxicam or a placebo at the time of tail docking for females and tail docking plus castration for males, as described in Table 1.

† One-way ANOVA for ADG comparisons and chi-square test for mortality comparisons.

A total of 32.6% of the pigs in the placebo group isolated themselves from the other pigs in the group compared to 13.5% in the meloxicam group. Lying down was significantly different between males and females ($P < .05$). A total of 90.6% of males showed lying-down behavior compared to 69.2% of females. Table 3 includes the summary statistics of each specific behavior to assess post-operative pain by treatment and gender. Tail-jam, isolation, and head held low tended to be different ($P < .10$) between treatment groups and gender.

The final logistic regression model included isolation, tail-jam, gender, and the interaction tail-jam × gender. Pigs in the meloxicam group were less likely to be isolated than the placebo group (OR = 0.26; 95% CI, 0.09-0.76; $P = .01$). In addition, piglets in the meloxicam group were less likely to have a behavior of tail-jam than the placebo group (OR = 0.11; 95% CI, 0.02-0.63; $P = .01$). However, the interaction of tail-jam × gender showed that this behavior varied by treatment and between males and females ($P = .04$) (Table 3).

Cortisol concentrations. The average baseline concentration of cortisol in 12 pigs was 85.6 nmol per L before tail docking and castration. Baseline cortisol concentrations were significantly lower than concentrations 30 minutes after castration and tail docking ($P < .05$). Cortisol concentrations were not normally distributed and ranged from 28 to 839 nmol per L. In general, plasma cortisol differed significantly between males (160.4 nmol per L, SD 134.4) and females (82.7 nmol per L, SD 61.9) ($P < .001$). Summary statistics of plasma cortisol concentrations by treatment and gender are shown in Table 4. In the regression model, concentrations of cortisol were significantly lower at 60 minutes, 90 minutes, and 4 hours after processing than at 30 minutes. In the regression model, concentrations of cortisol decreased significantly at 60 minutes (40.6 nmol per L lower than at 30 minutes), 90 minutes (85.6 nmol per L lower than at 30 minutes), and 4 hours (80.9 nmol per L lower than at 30 minutes). Cortisol concentrations tended to decrease between 60 minutes and 90 minutes after processing by 49.4 nmol per L ($P = .06$). The concentration of cortisol at 90 minutes post processing was lower in meloxicam pigs than in the placebo group ($P < .001$), by 49.4 nmol per L when controlling for time and gender. The concentration of cortisol in gilts at 90 minutes post processing was significantly lower than in barrows ($P < .001$), by 76.7 nmol per L. However, a significant interaction showed that cortisol concentrations varied by treatment and gender ($P < .001$) (Table 4). No significant interactions were observed between treatment and times of blood collection.

Discussion

Overall, meloxicam administered 30 minutes before processing did not result in an improvement in ADG or survival over the subsequent 2-week period. These results are in agreement with other reports, which found no relationship between pain-control treatment at processing and weight gain.[7,8] A study[10] using older pigs noted a tendency for castrated piglets to isolate themselves and miss suckling opportunities. One explanation for why this does not appear to happen in piglets under a week of age is that the activity of suckling provides some analgesia or calming effect.[11] Clearly, if the pain and stress of processing does not disrupt nursing, then growth rate is not likely to be improved with administration of an analgesic. Preweaning growth rates in pigs can be quite variable depending on a variety of factors, including genetic potential, environmental conditions, availability of nutrition, and stressful events.[12] In the present study, it was noted that important factors affecting growth included the weight of piglets at the time of processing, litter size, and age of the sow, and it was important to control for these factors when attempting to determine the effects of analgesia. It is possible that there were confounding factors that were not evaluated in the current study. For example, some litters contained piglets that had been fostered in during the first 48 hours after birth. By 5 to 7 days of age, the litters were expected to have stabilized with regard to teat order and social hierarchy, but ideally this variable (fostering) should have been controlled and this is a limitation of the study.

Mortality in general was not affected by

Table 3: Summary statistics of piglet behaviors used to assess post-operative pain between gender and treatment groups in a subset of piglets treated with meloxicam or a placebo*

Behavior†	Placebo		Meloxicam		*P*‡
	Males (%) n = 26	Females (%) n = 23	Males (%) n = 27	Females (%) n = 25	
Lying down	23 (88.5)	18 (78.3)	25 (92.6)	18 (72)	.19
Walking	13 (50)	12 (56.5)	13 (48.1)	13 (52)	.94
Standing	11 (42.3)	6 (26.1)	10 (37.0)	9 (36)	.69
Isolated	10 (38.5)[a]	6 (26.1)[a]	5 (18.5)[a]	2 (8)[b]	.06
Tail-jam	9 (34.6)[a]	3 (13.0)[ab]	2 (7.4)[b]	5 (20)[ab]	.08
Tail-wiggle	5 (19.2)	5 (21.7)	4 (14.8)	4 (16)	.91
Head low	5 (19.2)[a]	0[b]	1 (3.7)[ab]	2 (8)[ab]	.06
Tremble	1 (3.8)	4 (17.4)	2 (7.4)	1 (4)	.36
Scooch	1 (3.8)	3 (13.0)	3 (11.1)	1 (4)	.56

* Behaviors and treatments described in Table 1. Pigs described in Table 2.

† Behavioral observations after tail docking in female piglets and tail docking plus castration in male piglets for the period immediately following treatment with meloxicam (52 piglets) or placebo (49 piglets), and for 30 minutes afterwards.

‡ Chi-square test.

[ab] Within a row, values with no common superscript are significantly different ($P < .05$; chi-square).

Table 4: Mean plasma cortisol concentration (± standard deviation) at 30, 60, and 90 minutes (min) and 4 hours after processing (tail docking for females, and tail docking plus castration for males) in piglets treated pre-operatively with meloxicam or a placebo*

Time	Meloxicam		Placebo		*P*†
	n	Plasma cortisol (nmol/L)	n	Plasma cortisol (nmol/L)	
Males					
30 min	12	169.4 ± 50.8	13	344.4 ± 150.0	< .01
60 min	7	107.9 ± 29.6	14	292.5 ± 210.0	.02
90 min	25	79.2 ± 44.7	20	156.4 ± 105.4	< .01
4 hours	19	106.2 ± 60.0	13	124.6 ± 48.9	.45
Females					
30 min	10	106.7 ± 71.3	13	117.2 ± 107.4	.13
60 min	10	78.1 ± 38.6	13	67.7 ± 24.1	.49
90 min	19	98.8 ± 62.7	19	72.4 ± 28.8	.46
4 hours	17	89.4 ± 53.6	12	79.8 ± 35.7	.92

* Treatments described in Table 1. Blood was collected from individual piglets only once.

† Kruskal-Wallis one-way ANOVA.

treatment except in litters nursed by older sows (parities > 5). Among the litters of older sows, piglets receiving a placebo were 4.4 times more likely to die than pigs from the same sow age group that received meloxicam at processing. It is possible that because mortality is higher among the litters of older sows, the benefits of pain control may be more obvious in this subset of litters.

The lack of obvious gains in piglet performance as a result of medication with meloxicam suggests that pork producers cannot factor in an economic payback from instituting this as part of the farm's standard operating procedures. The reason for using meloxicam needs to be based on the animal welfare benefits of this regimen. Evidence from this trial and others suggest that meloxicam does reduce pain associated with tail docking and castration.

The present study found that plasma cortisol concentrations up to 90 minutes post castration were significantly lower in piglets that received meloxicam than in piglets that received the placebo, suggesting a reduction in the effects of castration on stress and pain when meloxicam is administered. Similar to the present study, Keita et al[7] found that plasma cortisol concentrations were significantly lower 30 minutes post castration with pre-operative administration of meloxicam, compared to concentrations in a placebo group. Also, in agreement with the present study, Prunier et al[13] observed that plasma cortisol concentrations in piglets were higher 15 to 90 minutes after castration than after sham castration or no handling, with no difference between the sham-castrated and not-handled groups. In addition, Prunier et al[13] reported that peak concentrations of plasma cortisol were found between 30 and 60 minutes after surgical castration, and that the return to pre-surgery concentrations occurred within 3 hours after the procedure. The present study supported this finding, with no significant difference in plasma cortisol concentrations between treatment groups 4 hours after castration.

There are limitations of the use of cortisol concentration as an objective indicator of stress and pain in response to painful procedures such as castration. For example, cortisol concentrations may become elevated as a result of stresses such as handling,[2] or vary over the course of the day. However, research suggests that increased concentrations of plasma cortisol after castration can be attributed mainly to the procedure itself, as they are of much lower amplitude and duration in sham-castrated pigs than in surgically castrated animals, and this difference is likely related to pain or tissue damage.[13]

Tail docking did not seem to elicit a physiological stress response in female piglets, suggesting that there is an insufficient nociceptive stimulus caused by tail docking. These results are supported by Prunier et al,[13] who also found no significant changes in plasma cortisol concentrations after tail docking. Similarly, Sutherland et al[14] found that anesthetic treatment was not effective at significantly changing the physiological or behavioural response from tail docking in pigs. They found that cortisol concentrations were higher in tail-docked pigs than in control-handled pigs 60 minutes after tail docking, and Noonan et al[4] observed that behaviors such as tail-jamming and tail-wagging were greater in tail-docked pigs than in control-handled pigs. These results suggest that pigs do experience pain during and in the hours after tail docking, but the results from the present study demonstrate that these effects may be of short duration and may not be improved by administration of an analgesic.

Behavioural indices such as vocalizations, postures, specific pain-related behaviors, and general behaviors are relevant parameters to assess pain and discomfort induced by painful procedures.[15] However, behavioral measurements tend to be subjective, and observers must be kept "blind" to the treatment. In addition, behavioral indices of pain are difficult to assess because there is so much individual variation between animals, and pain-related behaviors tend to be more difficult to assess after the acute phase.[1] Despite these limitations, the present study found that administering meloxicam to piglets before castration resulted in less isolation behavior. This is in agreement with previous studies which have demonstrated that castrated piglets avoid social contact with their littermates.[1,2] Isolation

behavior is unusual for such social animals as pigs and suggests that the piglets may be experiencing pain or adapting a protective strategy to avoid being bumped and jostled, which might generate pain.[1,15] In the present study, tail-jam, isolation, and head held low tended to be different between treatment groups and genders. An increase in tail-jamming behavior has been reported by other researchers observing pigs after undergoing tail docking compared to non-processed piglets, and they have suggested that this behavior may indicate distress.[4]

Although it is common for piglets to vocalize when they are handled, a clear difference between vocalizations produced when being handled and when being surgically castrated exists.[16] Piglets produce high frequency vocalizations of higher intensity and longer duration during surgical castration than when they are sham-castrated or castrated under local anaesthesia.[16] It has been suggested that a parameter describing a single moment in the call, such as peak intensity, is more representative than parameters describing mean intensity.[8,17] Measuring peak amplitude is a practical approach when conducting a field trial, because many devices are readily available for occupational health reasons, but peak frequency might be a better indicator of pain.[16] The present study did not find a difference between the peak amplitudes of cries produced among treatment groups. In previous studies, the use of analgesics has been useful in mitigating the post-operative pain experienced in the hours after the procedure, but not effective in blocking the acute pain associated with the surgery itself, in particular the severing of the spermatic cord.[7,8]

This current study supports earlier trials that have shown that pre-operative administration of meloxicam contributes to the relief of stress and post-operative pain associated with castration in piglets.[7,8] No negative side effects were noted when piglets were treated preoperatively with meloxicam, in that the growth rate and mortality overall were similar with respect to treatment and gender. Van Beirendonck et al[18] found that piglets surviving the nursing period were significantly heavier at birth than piglets that died before weaning, and that mortality rate was higher in processed piglets than in non-processed piglets. Birth weights were not recorded in the present study, but mean weights at castration and tail docking were similar between males and females. There were no controls that did not undergo at least one surgical procedure, and therefore no comparison could be made to determine if processing affected performance. Contrary to the current study, Baxter et al[19] investigated sex-biased mortality and found that males had significantly higher preweaning mortality than did females, despite having a higher average birth weight. These authors suggested that male piglets tend to suffer more from crushing by the sow and disease-related deaths than do females, and males also show less effective thermoregulation than do females.[19] Possibly in a herd with higher preweaning mortality and either a lower level of management or a higher level of disease challenge than the herd used in this study, this difference in gender may be observed.

In summary, pork producers in the future may need to consider using pain control as part of their standard operating procedures in order to meet the requirements of industry codes of practice and the expectations of the general public. The results of this study provide information that might be helpful for producers and their health advisors considering using meloxicam as a preoperative analgesic or anti-inflammatory medication.

Implications

- Routine treatment with meloxicam prior to castration and tail docking does not improve growth during the suckling period, but may reduce mortality in certain circumstances, such as in litters nursed by older sows.
- Behavior observations and analysis of cortisol concentrations indicates that meloxicam treatment does reduce post-operative pain.

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Conflict of interest

None reported.

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